SIMONINI & KIRKPATRICK

Design and Investigation of Cost of an Artificial Ice Skating Rink

Mechanical Engineering

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DESIGN AND INVESTIGATION OF COST OF AN ARTIFICIAL ICE SKATING RINK

BY

PAUL CHARLES SIMONINI
ROBERT JUDSON KIRKPATRICK

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

1911

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May 29 1911

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Paul C. Simonini and Robert J Kirkpatrick

ENTITLED Design and Investigation of Cost of an Artificial Ice Skating Rink

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

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DESIGN AND INVESTIGATION OF COST OF AN ARTIFICIAL ICE SKATING RINK

Mechanical Refrigeration and its Applications--The artificial production of cold has been known to mankind for hundreds of years, but it is only recently,since the introduction of improved machinery, that artificial refrigeration has been applied to the commercial industries on a very large scale. The production of ice was probably the chief incentive to the work of early inventors, but there is no doubt that the preservation and transportation of food products, and the industrial requirements connected with cold storage, were very largely responsible for the remarkable development of artificial refrigeration of today.

The process of mechanical refrigeration as used in our modern refrigerating plants, is very simple as compared with many other establishments in which machinery is used; still it is not so easy to understand the fundamental principles upon which good operation depends. The basis of all our modern practical methods are almost identical with the methods of ancient times; that is, the thermodynamic principles are the same, the improvements being more on the mechanical process relating to the construction and practical working of the machinery, as well as to the distinctive characteristics of different refrigerating systems.

The uses to which mechanical refrigeration has been ap-

plied are many and varied. Nearly every business of any consequence has such a system for cooling and storing its perishable merchandise. Mechanical refrigeration is used for cooling halls theatres, freight cars, cold storage houses, and the provision or store rooms on board the ocean vessels, for the preservation of fruits, vegetables, milk, butter, eggs, meat and all kinds of perishable products. It is also used in the manufacturing industries, such as brewing, sugar refineries, chocolate manufacturing, rubber works, glue works, and in the manufacture of butter, ice cream, gelatine plates for photography, candle making, and in the manufacture of dynamite.

Some peculiar and rare uses to which mechanical refrigertion has been applied are: sinking of caissons and in connection with tunnel work, also in sinking mine shafts by freezing strata of water. Another use is the cooling of air for drying purposes. The latest use to which mechanical refrigeration has been put is for the purpose of amusement, and recreation, in the form of artificial ice skating rinks.

In these industrial uses just mentioned, only a moderate degree of refrigeration is required. The working temperatures are rarely lower than zero degrees Fahrenheit. However, in certain processes considerably lower temperatures are employed.

History of Skating Rinks--The recent growth of mechanical refrigeration has no doubt had its influences on the rapid progress and the great number of ice skating rinks which have been built in the last few years. A great many large cities in Europe, Australia, and the United States have one or more artificial ice skating rinks. It is very evident that there is no use

for the artificial ice skating rink in countries which have extremely hot or cold weather conditions; this perhaps explains why rinks are built only in the countries above-mentioned. Although mechanical refrigeration dates back for a number of years as previously stated, its application to ice skating rinks is so recent that no books have been written on the subject and very few practical data are available, except from the application of refrigeration to other industries.

There are about thirty-five artificial ice skating rinks in existence, and only about twenty are now in operation. All of these rinks are enclosed and roofed in, with the exception of two which are open air rinks, one located at Vienna, Austria, and the other at Detroit, Michigan. Both have been opened within the last year and are apparently successful. Another open-air rink has recently been proposed for the use of the students of Syracuse University, New York. Its installation is not yet a certainty since the details have not yet been completed.

Artificial ice skating rinks are more numerous, and more successful in Germany than in any other country, possibly with the exception of Australia.

Berlin has three rinks which are very successful and are operated the entire year. The Potsdam Street rink is one of the oldest rinks in Europe, having been installed in 1890. It is also the largest in Europe, and has an area of twenty-five hundred square meters, or about twenty-six thousand nine hundred square feet of surface. There are twenty-five thousand meters, or about eight-two thousand feet of pipe for the freezing surface. The plant is operated by sulphur dioxide compression

machines of five hundred sixty calories per hour capacity, which is equivalent to about two hundred tons of refrigeration per twenty-four hours. The compressors are driven by a three hundred horsepower engine. The other two rinks in Berlin are the "Ice Palace" on Luther Street, and the rink on Friedrich Street The latter has only recently been installed. Other German rinks are located at Hannover, Nuremberg, Frankfurt, and Dresden.

The largest rink in America is the St. Nicholas rink in New York City; other American rinks are located at Chicago, Boston, Cleveland, San Francisco and Pittsburg. The most important rinks may be tabulated as follows in the order of their respective sizes.

LIST OF SKATING RINKS

Potsdam Street	Berlin, Germany	26,910 sq.ft.	SO_2
St. Nicholas	New York, N.Y.	22,000 " "	NH_3
Ice Palace	Chicago, Ill.	20,000 " "	NH_3
Shenley Park Casino	Pittsburg, Pa.	16,000 " "	NH_3
Glacarium	Sydney, N.S.W.	14,000 " "	NH_3
----------	Adelaide, S.A.	14,000 " "	NH_3
Nat'l Sk. Palace	London, England	13,500 " "	CO_2
---------	San Francisco,Cal.	10,000 " "	NH_3
Palais de Glace	Lyons, France	9,000 " "	CO_2
Palais de Glace	Paris, France	7,700 " "	NH_3
Friedrich St.	Berlin, Germany	------ " "	SO_2
---------	Hannover, Germany	------ " "	NH_3
---------	Frankfurt, Germany	------ " "	NH_3
---------	Nuremberg, Germany	------ " "	CO_2
Niagra	London, England	------ " "	NH_3
---------	Dresden, Germany	------ " "	NH_3
Dartford Hall	Glasgow,Scotland	------ " "	NH_3
---------	Cleveland, Ohio	------ " "	NH_3
Luther St.	Berlin, Germany	------ " "	NH_3
---------	Boston, Mass.	------ " "	NH_3
---------	Vienna, Austria	------ " "	NH_3
---------	Detroit, Michigan	------ " "	NH_3

Note:- All of the above rinks use the brine system.

Proposition--It is proposed to make a general investigation of the possibilities of an open air ice skating rink for the use of the student body at the University of Illinois during the months of December, January, and February. The rink is to be of sufficient size to accommodate two hundred skaters without over-crowding, and is to be equipped with machinery and auxiliaries of sufficient capacity to meet ordinary weather conditions experienced in Urbana during the winter months. A table of approximate total cost of installation and maintenance together with a general layout of the rink and equipment, is submitted in the following pages.

Location--The most important factors in determining the location of this rink are the desirability of being near the men's gymnasium, and also near the power plant. Another important matter to be considered is the housing of the machinery in a suitable building as near the rink as possible, to keep down the losses due to transmission. The cost of erecting a new building would be a large item, and if one of our present buildings could be utilized, quite a large saving in first cost would be realized.

One of the first locations proposed was the quarter-mile running track, located at the south end of Illinois Field. This would make an ideal site for a skating rink were it not for the fact that it would be necessary to take up the freezing pipes each spring and replace them in the fall in order that the track might be used for running purposes in the meantime. The taking up of the pipes has been found to be impractical owing to the corrosion to which the joints are subjected as well as to the

added expense of handling. Another location proposed was a lot one hundred by one hundred and fifty feet, located just east of the power plant. This location was rejected on account of the objectionable slope of the land. After a careful consideration of the sites offered, it was found that the present location of the men's tennis courts situated between Wright Street and Burrill Avenue is the most desirable.

These courts are approximately one hundred fifty feet wide and two hundred feet long, which is ample room for a rink that would accommodate six hundred people in case it should be desirable to enlarge the rink at some future time. They are near the gymnasium and power plant, and the freezing pipes may be laid permanently if a cover is provided in order that they may not present an unsightly appearance when not in use.

Size of Rink--The size of rink necessary for two hundred people is approximately five thousand square feet with an allowance of twenty-five square feet per person. This would make too small a rink for hockey and other ice sports, however, and it was decided to enlarge the rink to seventy-five by one hundred and forty feet, or ten thousand five hundred square feet. This gives ample space for bleachers and banking at either end. For location of courts see PLATE I.

Location of Machinery--A suitable location for the necessary machinery is to be found in the basement of the wood shop. An available floor space of approximately two thousand seven hundred square feet could be formed by excavation, which would not interfere materially with the present equipment. This space would give ample accommodation for all equipment and auxiliaries

more space being available if necessary for expansion.

Conditions--The fact that the rink is out of doors and exposed to the direct rays of the sun and warm winds, makes the problem quite difficult and uncertain. Statistics of the University Weather Bureau show that the temperature of the average warm day in winter is about 55° F. It was found that it would require enormous engines to counteract the heat of the sun's rays on extremely warm days, making it more feasible to use engines capable of keeping the ice hard under ordinary conditions. The plant would be shut down when it could no longer furnish the necessary refrigeration, and started again when colder weather conditions prevailed.

The preliminary calculations were based on experimental data collected by such well known physicists as Abbott, Pouillet Voille, Langley, and Crova. The results obtained by these men show that the sun will transmit from 1.7 to 2.8 calories per sq.cm. per minute, or from 6.3 to 10.6 B.t.u. per sq.ft. per minute, to an absorbing surface at right angles to the sun's rays. An assumed value of 7.0 B.t.u. per sq.ft. per minute gave such impractical results, due to wind velocity and other atmospheric conditions, that another basis had to be used for calculating the necessary requirements.

The results of Messrs. McKinnie and Wooten, obtained in Urbana during the past two years in connection with their thesis work, was adopted as being best adapted to this proposition, as they show the actual conditions to be met with. The following represent average observations taken on days when the weather was even warmer than 55° F. Readings were as follows:

March 31, 1910--Sky clear, hot sun

94 B.t.u. per sq.ft. per hour

April 7, 1910--Sky hazy, very little sunshine

67 B.t.u. per sq.ft. per hour

Although these readings were taken at a later date than it is planned to have the rink in operation, the same conditions would probably prevail for short periods during December, January and February. As a basis for calculations, 85 B.t.u. per sq.ft. per hour was assumed as the maximum amount of radiation that the machinery would be called upon to counteract. Of course these conditions will prevail for only a part of the day and it will not be necessary to have the plant in operation over night.

For insulating from the ground, the usual method is to put in a sand filling and lay the freezing pipes on sleepers just above this. It has been found that sand transmits heat approximately three times as fast as bituminous coal ashes, and two and one half times as fast as anthracite ashes. For this reason ashes will be used as a filling. (see PLATE II)

No provision has been made for freezing the ice surface for the first time, when an unusual amount of refrigeration will be required to cool the system itself and bring the water down to the freezing point. In order to accomplish this and at the same time prevent the water from soaking into the ground and being lost, a day when the temperature is below the freezing point must be selected, and the water sprayed on the pipes while the machine is running until a small layer of ice is formed, thick enough to prevent additional water from soaking through. The rink can then be flooded and frozen quickly with the aid of the

low outside temperatures. In case the surface becomes rough and worn down in places, due to heavy skating, a little warm water will melt the surface, which can then be frozen smooth during the night when it will not interfere with the skaters.

REFRIGERATION SYSTEM.

Brine System--There are two principal systems of mechanical refrigeration in use, namely, the brine system and the direct-expansion system.

In the brine system refrigeration is brought about by the evaporation of liquid anhydrous ammonia, in the expansion coils, which are submerged in a tank containing brine. A solution of calcium cloride is preferable because the temperatures can be obtained without having the brine freeze. The brine gives up its heat to the ammonia and becomes very cold; it is then circulated, by means of a pump, through the brine pipes under the skating surface, where the heat is taken up by the circulating brine and the pond becomes a hard frozen mass. The ammonia, after it has expanded, is compressed again by the ammonia compressor, and then passes to the ammonia condenser. The ammonia is condensed by cold water which is brought in contact with the ammonia pipes of the condenser. The water absorbs the heat which the ammonia has acquired during compression as well as the heat it has absorbed in becoming a vapor in the expansion coils. the ammonia then becomes a liquid again due to both pressure and the withdrawal of heat and is then ready to repeat the cycle of operations.

Direct-Expansion System--In the direct expansion system the ammonia is passed through an expansion valve and then is admitted directly into the freezing coils under the rink surface

where the heat from the water is taken up directly by the ammonia, thus doing away entirely with the brine.

Advantages and Disadvantages of the Systems--Each of the systems has certain advantageous features, which are dependent on the conditions under which the system is operated. The advantages of the brine system may be enumerated as follows:

(1) Much less ammonia is required with this system than for the direct-expansion system.

(2) The ammonia system is not spread over a large area but is located in or near the engine room under the care of one attendant, thus requiring less attention than the direct-expansion system would require.

(3) Owing to the large amount of circulating brine, the temperatures are more easily regulated with the brine system; then again the brine can be circulated for several hours after the compressor has been stopped, and still keep the ice surface hard. This cannot be done with a direct-expansion system, because when the machine stops the process of refrigeration also stops. It is, therefore, necessary to run continually with this system, if the out-door temperature is warmer than 32° F., while with a brine system the machine can be shut down at night if desired. Then again it is a decided advantage for the brine system to be able to shut down the machine for repairs when necessary.

The advantage of the direct-expansion system may be enumerated as follows:

(1) This system is much simpler and cheaper to install since there is no intermediate agent, such as brine to be circu-

lated. The brine tank, expansion coils in brine tank and the brine pump can be dispensed with.

(2) The economy of the direct-expansion system is a decided advantage over the brine system. In the first place the power to operate the brine pumps is saved, and also the temperature of the ammonia in the expansion coils must be much lower in the brine system thus giving less economy of power.

Reasons for Choice of Brine System--The brine system is generally preferred where uniform temperatures are required, for ease of temperature regulation, where less attention must be given to the operation, and where there is objection to the amount of ammonia leakage.

With a direct-expansion system, any leakage of ammonia would be objectionable for the skaters. Furthermore, it would be difficult to remedy matters in case of leaks.

The main reasons which are decidedly in favor of the brine system for ice skating rinks is the temperature regulation and the fact that the compressor can be shut down temporarily for repairs and at night, as previously stated. These advantages more than counteract the advantages of the direct-expansion system and completely justify the selection of a brine circulation system.

The reasons for using ammonia as the refrigerating medium in preference to carbon dioxide, chloride of methyl, ether, or sulphur dioxide are perhaps the cheapness of ammonia, the ease with which it may be handled, and the many advantages it possesses under certain working conditions Ammonia is probably used more than all the other media combined. The principal reason

why ammonia has been given the preference is because it has such a high latent heat of vaporization, being 555 B.t.u. at zero degrees Fahr. against 125 B.t.u. for carbonic acid. There are some compensating advantages in using carbonic acid on account of its high specific gravity, which makes its heat of vaporization much greater for a given volume than ammonia.

Refrigeration as Applied to Skating Rinks--It is remarkable to note the great number of artificial ice skating rinks (see Page 5) that are operated on the brine system, with ammonia for a medium. Very few rinks are operated on the direct-expansion system with ammonia for a medium. At the Chicago World's Fair in 1893 a long narrow surface of ice in connection with a toboggan slide was operated with the direct-expansion system, and was very successful.

COMPRESSOR

Ammonia Compressor--The ammonia compressor may be operated by steam, electric, water, or any other power, whether wasteful or economical without affecting its quality or efficiency as a compressor. It is, therefore, preferable to obtain the following desirable qualities or conditions that should be fulfilled in an ideal compression machine:

(1) On the suction stroke the compression cylinder should fill with gas at a pressure as little below that in the expansion coils as possible, and the outlet valve should be tight.

(2) The piston and piston rod should be a tight fit in order to prevent leakage, and at the same time have a minimum amount of friction, which would involve extra power to run the compressor and also generate heat.

(3) On the compression stroke the inlet valve should not permit any leakage of ammonia, and the entire contents of the cylinder, except a minimum clearance volume, should be discharged through the outlet valve at a pressure as little above that of the condenser as possible.

(4) The machine should be self-contained, so that it may be easily and cheaply erected.

(5) For a large machine the compressor should be double-acting instead of single-acting.

(6) Loss of power, wear and tear on a compressor should be

prevented by having a minimum friction in bearing and working parts.

(7) The pistons and valves should be easily accessible for examination and renewal of broken or worn parts.

(8) All wearing surfaces should be arranged so that they can be easily adjusted to take up the wear.

The advantages of any particular make of compressor over some other make depends chiefly upon the design and construction of its working parts, but since there are so many excellent compressors on the market, the details of construction will not be taken up. There are two principal types of compressors, namely, the horizontal and the vertical compressors. In connection with this work the horizontal machine will be used. It will be belt driven by a variable speed electric motor in order to economize space and in order to lower the first cost, as well as to avoid the inconvenience of installing steam pipes.

The size of the compressor was determined by calculating the refrigerating capacity in tons of refrigeration per twenty-four hours, assuming 85.7 B.t.u. absorbed per square foot of ice surface per hour.

Size of Compressor--For a rink 140 ft. by 75 ft. the refrigeration required is

$$\frac{75 \times 140 \times 24 \times 85.7}{144 \times 2000} = 75 \text{ tons per twenty-four hrs.}$$

A machine of this capacity requires a cylinder 14 in. by 30 in. driven at sixty revolutions per minute. About one and one half horse power is required per ton of refrigeration. Normally, therefore, about 112 horsepower will be required. A 125 horse-

power D.C. variable speed induction motor will be installed, thus giving a margin of about 10 per cent for overload.

PIPING

Several factors enter into the determination of the size of freezing pipes required. In order to obtain an even distribution of refrigerating effect, the pipes must be of small diameter and placed close together while still of sufficient size to carry the volume of brine required without excessive loss of head due to friction. The heat conducting power of ice at a temperature near the freezing point has been found to be 10 B.t.u. per sq.ft. per hr. per degree difference in temperature through a layer of ice one inch thick. Allowing one and one quarter inches of ice above the top of the freezing pipes it was found that one and one quarter inch pipes,placed four inches center to center, would give a fair distribution of cold without excessive loss of head due to friction. By using one inch pipe placed on three inch centers an even distribution can be obtained, but the loss of head due to friction is excessive, and the first cost greater than for the same spacing of the larger pipe. For these reasons it was decided to use one and one quarter inch pipe placed on four-inch centers.

Most builders of refrigerating machinery recommend double strength wrought iron pipe for a brine circulation, but on account of the extremely low pressure to which these pipes will be subjected, as well as the lesser initial cost, ordinary single thickness wrought iron pipe will be found to answer the purpose

as well as that of heavier material. The amount of pipe necessary will be

$$\frac{12 \times 75}{4} \times 140 = 31{,}500 \text{ lineal feet}$$

In order to obtain the most even distribution of the cold, the colder pipes containing brine fresh from the header are made to alternate with pipes carrying the returning brine, as shown in PLATE III. Each pipe in traveling across the rink and back through return bend must absorb 85.7 B.t.u. per sq.ft. of ice surface above it, or

$$\frac{75 \times 2}{3} \times 85.7 = 4280 \text{ B.t.u.}$$

The internal area of each pipe is 0.0104 sq.ft. and the weight of calcium brine is 63 lbs. per cu. ft. This gives 0.66 lb. of brine per running foot of pipe. Assuming the velocity of the brine as 1200 ft. per hour, a total of 800 lbs. per hr. will flow through each pipe in an hour. The specific heat of brine is 0.85, therefore, 800 lb. of brine will be capable of absorbing 0.85 x 800= 680 B.t.u. for each degree temperature difference.

$$\frac{4280}{680} = 6.3^\circ \text{ F. temperature difference between inflow-}$$

ing and out-flowing brine which is well within an assumed limit of 10° temperature difference. Thus with an ice surface temperature of 25° F. and a difference in temperature of 10° between between the ice and brine, the required temperature in the brine tank would be 5°.

The headers necessary to feed two hundred ten 1-1/4 in.

pipes, assuming a velocity in the header of 40 ft. per minute, would be eight inches in diameter if tapped as shown in PLATE III. By increasing the velocity slightly the diameter could be reduced to seven inches. The velocity in the mains may be much higher, thereby reducing the required diameter to six inches, insulated as shown in PLATE II and placed below the level of the street.

In order to insure uniform circulation, each freezing pipe is provided with a valve located close to the supply header. These may be regulated to take care of any variation in circulation which occurs or which it may be desirable to make. Throttling each pipe near where the supply header is tapped will prevent an increased circulation in these pipes, due to a variation of the velocity head.

BRINE PUMP

The weight of brine that will flow through the system per hour may be found by multiplying the amount through each freezing pipe by the number of pipes; thus

Weight per hour=800 x 210= 168000 pounds

This flow is equivalent to 330 gallons per minute, but in order to allow for an increase in the brine circulation, should this become necessary, a 400 gal. pump will be used. The centrifugal type is preferred inasmuch as it is to be driven by a motor. Furthermore this type of pump gives a steadier flow than the direct-acting pump.

The power required for driving may be determined from the head pumped against. This will be a friction head only, as the back pressure equalizes the lift. For a velocity of twenty ft. per minute the loss of head due to friction in a 1-1/4 in. pipe, including bends may be taken as 1.5 ft. per thousand feet of pipe. This gives a total friction head of 48 ft., but if the discharge is increased to 400 gallons per minute the head pumped against will be 60 ft. Under this condition the pump will require 6.3 actual horsepower. Assuming an efficiency of 65% a motor of practically 10 horsepower will be required. The actual work done on the brine is absorbed as heat and goes toward raising its temperature above the 6.3° difference in temperature calculated. This, however, will not bring it above the 10° temperature difference allowed.

BRINE TANK

In choosing a type of brine tank and cooler, the amount of storage capacity available plays an important part. In the double-pipe and shell types this capacity cannot be obtained without additional expense, but with the submerged type, storage capacity may be obtained by merely increasing the pipe spacing. The investigation of Mr.E.T.Skinkle shows that approximately 60 sq.ft. of surface is required per ton of refrigeration. For a 75-ton machine, this would mean 10,350 ft. of 1-1/4 in. ammonia piping, requiring a tank 25 ft. x 7 ft. x 12 ft. containing 432 pipes spaced on 5-1/4"centers. The storage capacity of such a tank would be 2000 cu. ft. of brine, capable of absorbing 1,200, 000 B.t.u from the skating surface while the compressor is idle. The weight would be in the neighborhood of 8600 lb. if the sides and bottom were of 1/4 in. sheet iron. An insulation of the following material would give a heat transmission of only 0.07 B.t.u. per sq. ft per hr. per degree difference in temperature between the brine and surrounding atmosphere: 7/8 in. sheathing, paper, 7/8 in. sheathing, 4 in. granulated cork, 7/8 in. sheathing, paper, 7/8 in. sheathing. This would mean a loss of only 4250 B.t.u. if the air were at a temperature of 60° F. in the vicinity of the brine tank.

The amount of calcium brine to be used should not exceed the capacity of the tank in order that the freezing pipes may be

emptied if necessary. For a minimum temperature of 5° F. the amount of calcium chloride used should not be less than 2.1 lb. per gallon or greater than 3.8 lb. per gallon. A solution of 2.15 lb. per gallon will be used, requiring 32,200 lb. of calcium chloride should it be necessary to fill the tank full.

AMMONIA CONDENSER

In order that the expansion of the ammonia may take place at a low temperature, it is necessary to cool the compressed ammonia gas until it condenses. This is accomplished by means of a double pipe, atmospheric or submerged condenser. For economy of space the double pipe condenser will be used, as best adapted for this system.

Condensers of this type are furnished in sections rated in tons of refrigeration per twenty-four hours. The Fred. W. Wolf Company furnish a condenser of this type for a 75-ton machine consisting of six sections of twenty-four pipes each twenty feet long. The top rows of pipes are 2 in. in diameter, diminishing to 1-1/4 inch as the gas condenses and the volume occupied is less. The inside pipe is filled with cooling water which enters at the bottom meeting the coldest ammonia and travels to the outlet at the top.

The amount of cooling water required is found from the amount of heat taken from the rink plus that put into the ammonia in the form of work. The heat absorbed from the rink is

10,500 x 85.7= 900,000 B.t.u. per hr., and that put into the ammonia as work is

$$\frac{125 \times 33000 \times 60}{778} = 318,000 \text{ B.t.u.}$$

This gives a total of 1,218,000 B.t.u. per hr. to be taken away

by the cooling water or 20,300 B.t.u. per minute. Assuming a possible rise of temperature of the cooling water of 60° there would be required

$$\frac{20{,}300}{60} = 340 \text{ lb.} = 40 \text{ gallons per minute.}$$

This may be obtained from the University supply mains by means of a 2 in. main with globe valve for throttling.

OTHER AUXILIARY APPARATUS

A liquid ammonia receiver is to be provided to store the ammonia coming from the condenser before it reaches the expansion valve. The types of receiver vary with different makes of machines, the most common being a strong cylindrical tank of sufficient size to form a reserve supply of anhydrous ammonia which may be used after the compressor has been stopped.

In passing through the compressor cylinder a certain amount of oil becomes mixed with the ammonia. This can be removed by placing an oil separator or collector in the circuit between the compressor and ammonia condenser. This consists of a cylindrical vessel through which the hot gas passes, the oil being removed in much the same manner as that employed in separating oil from exhaust steam.

The expansion valve regulates the amount of ammonia delivered to the coils, thus controlling the back pressure. The Linde valve consists of a rotating cock set vertical and having several aperatures. The ammonia enters at the bottom,where any oil that may settle can be drawn off, and passes out at the top as the cock slowly revolves. An adjustment is provided by means of which the area of the apertures may be varied,thereby regulating the amount of ammonia passing through.

COST

In estimating the first cost of an installation of this kind, two distinct features demand attention. First, the cost of the apparatus and materials themselves, and second, the labor charges necessary to place the material in place ready for operation.

Owing to the reluctance of engineers and manufactures of refrigerating machinery to quote other than a total cost of installation, the itemizing of the various parts of the plant becomes a rather uncertain problem. In the following pages the writers have endeavored to give a fair estimate based on prices submitted by a number of competing firms.

Cost of Apparatus and Materials--

	$
75-ton horizontal double-acting ammonia compressor complete with condenser, liquid receiver, oil-separator, and all ammonia connections between the various apparatus...........................	4800.00
125-H.P. motor for driving compressor.........	950.00
Brine-tank, 7 ft. x 25 ft. x 12 ft. made of 1/4 inch sheet iron , insulated...........................	700.00
400- gal. brine pump direct connected to 10-H.P. electric motor................................	450.00
31,500 ft. 1-1/4 inch brine pipe and fittings complete with headers and valves..................	4500.00

200 ft. 6 inch cast-iron mains and valves............	100.00
10,350 ft. 1-1/4 inch ammonia pipe set in brine tank..	1900.00
32,200 lbs. calcium chloride at $12.00 per ton........	200.00
100 ft. insulation for mains.........................	45.00
80 gals. ammonia at $0.26 per lb.....................	175.00
400 ft. No. 00 copper wire insulated, and installed...	50.00
Foundations for apparatus............................	200.00
Sleepers for rink floor, 1400 ft. at $26.00 per M.....	37.00
700 ft. of lumber for banking at $27.00 per M.........	19.00
Total	$ 14,126.00

Cost of Installation--

Excavation of basement, 540 cu.yds. at $0.65 per yd...	$ 350.00
Excavation of courts, 730 cu.yds at $0.15 per cu.yd...	110.00
Loading and hauling dirt, 1270 cu.yds. at $0.20........	254.00
Installing 31,500 ft. pipe, headers and connections...	800.00
Installing mains and installation....................	30.00
Freight charges from Chicago.........................	140.00
Unloading from cars and hauling to rink..............	125.00
Hauling cinders and sand, 400 cu.yds. at $0.18........	72.00
Erecting machinery...................................	300.00
Total	$ 2,181.00

	$ 14,126.00
	2,181.00
Total Cost of Rink......	16,307.00

Prices Submitted--The following are approximate prices as quoted by some of the leading refrigerating firms in this country:

	$
Westerlin, Campbell & Co., Chicago, Ill.,	
Equipment complete	15,000.00
Fred. W. Wolf Co., Chicago, Ill.,	
Equipped and erected	16,000.00
Great Lakes Engineering Works, Detroit, Mich.,	
Equipment complete	14,000.00
Cleveland Ice Machine Co., Cleveland, Ohio,	
Equipped and erected	20,000.00
De La Vergne Machine Co., Chicago, Ill.,	
In operation	30,000.00
Artic Ice Machine Co., Canton, Ohio	
Equipped and erected	15,800.00

CONCLUSION

The data obtained in this investigation seem to indicate that a skating rink as outlined, capable of maintaining a hard frozen surface during the greater part of the winter, could be equipped and put in operation at a cost of $16,000.00. Experience has shown that the actual cost of a plant is from ten to twenty percent higher than the estimated cost, due to miscellaneous charges, etc. This would make the total cost near $18,000.

The cost of operation would be very slight, the plant requiring but one attendant while in operation, and one charge of ammonia and calcium chloride being sufficient for a whole season. The power required would be 100 kilowatts which could be taken from the University mains at small expense, making the total cost of operation about $650.00 for each season. In the summer when the rink is not in operation, the freezing pipes should be covered with some cheap material, easily removed in order that they may not present an unsightly appearance. At the beginning of each season the whole plant should be subjected to a frost test, and all leaks repaired before the rink is flooded.

PLATE I.

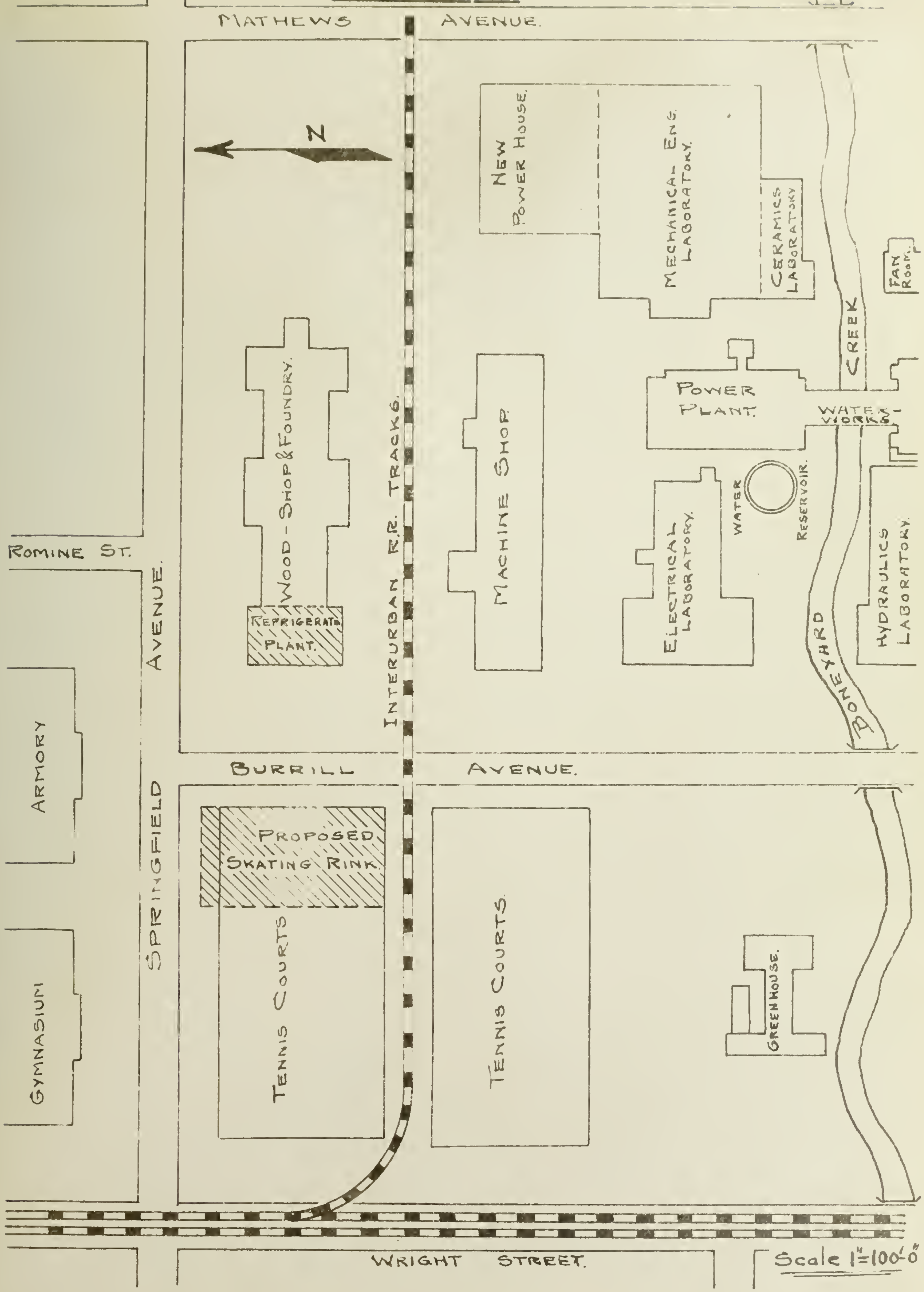
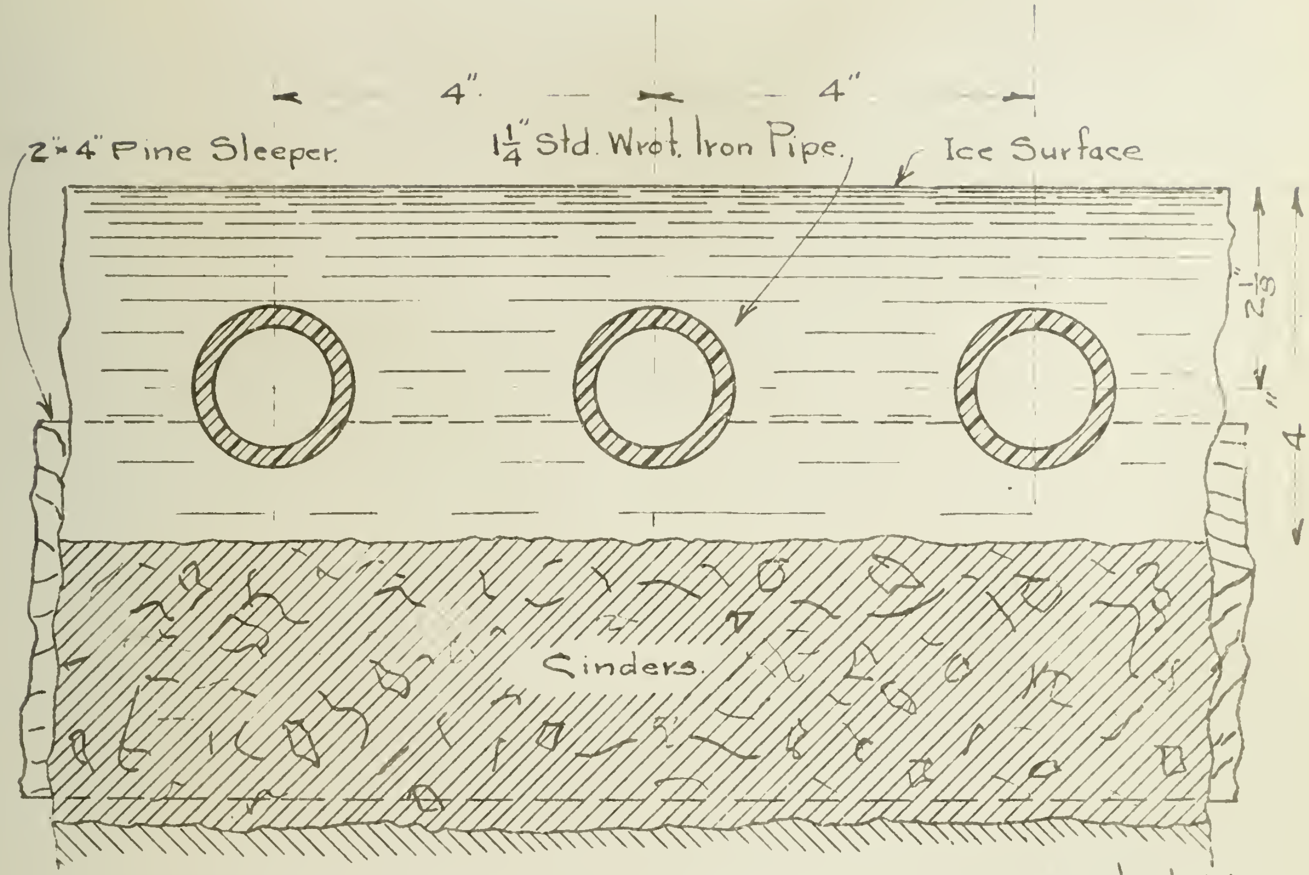
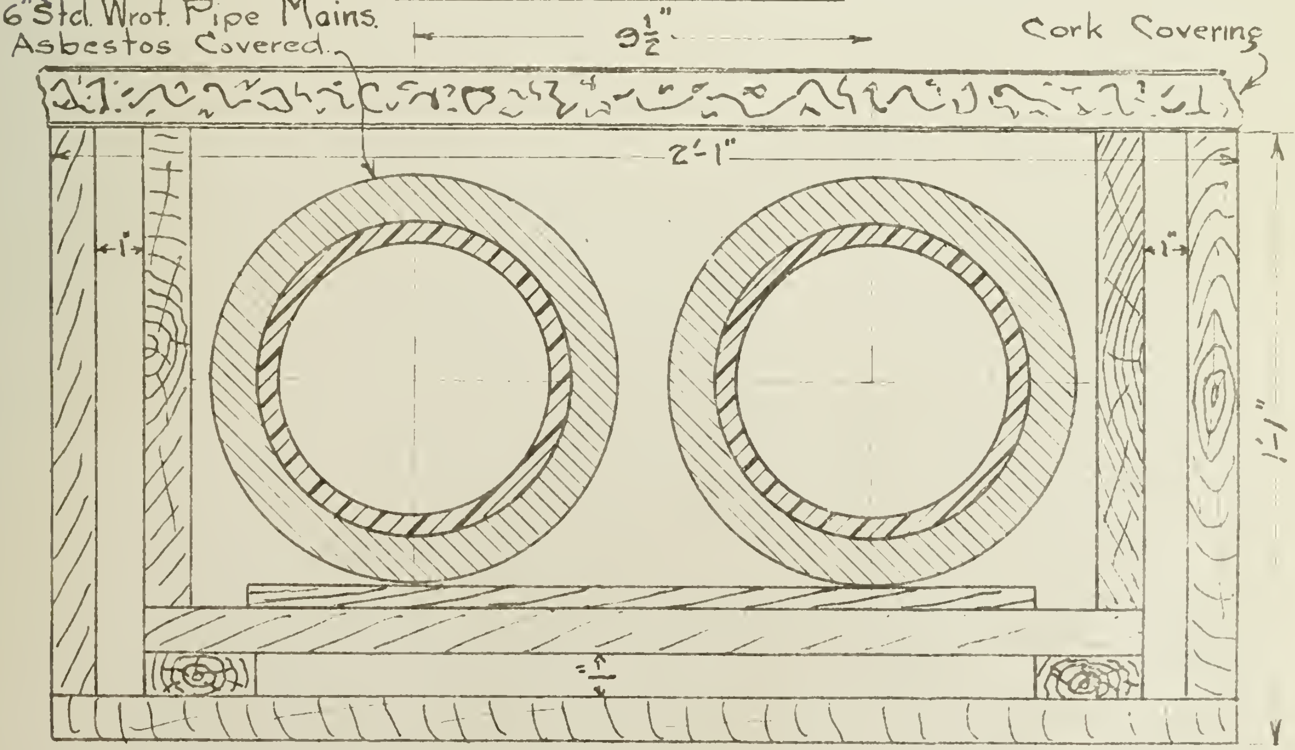

J. L.
MATHEWS AVENUE
N
NEW POWER HOUSE
MECHANICAL ENG. LABORATORY
CERAMICS LABORATORY
FAN ROOM
CREEK
WOOD-SHOP & FOUNDRY
REFRIGERATᴺ PLANT
INTERURBAN R.R. TRACKS
MACHINE SHOP
POWER PLANT
WATER-WORKS
WATER RESERVOIR
ELECTRICAL LABORATORY
HYDRAULICS LABORATORY
BONEYARD
ROMINE ST.
SPRINGFIELD AVENUE
ARMORY
GYMNASIUM
BURRILL AVENUE
PROPOSED SKATING RINK
TENNIS COURTS
TENNIS COURTS
GREENHOUSE
WRIGHT STREET
Scale 1"=100'-0"

PLATE II.



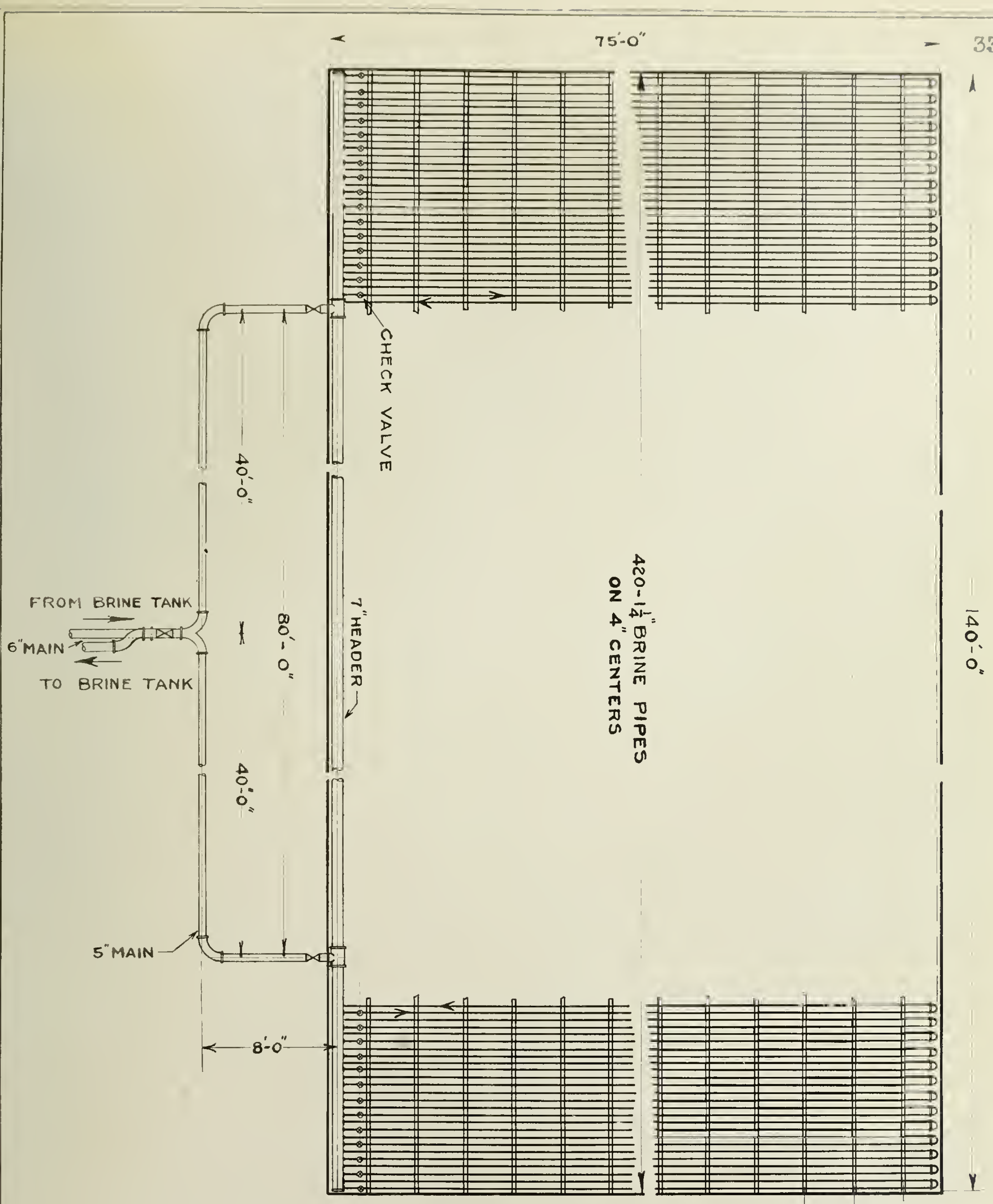
SECTION OF RINK.

Scale ½ Size

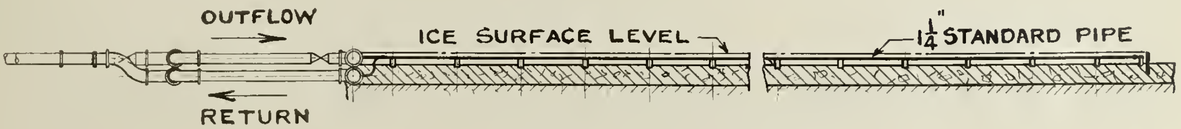


SECTION OF CONDUIT.

Scale ¼ Size.



PLAN ELEVATION

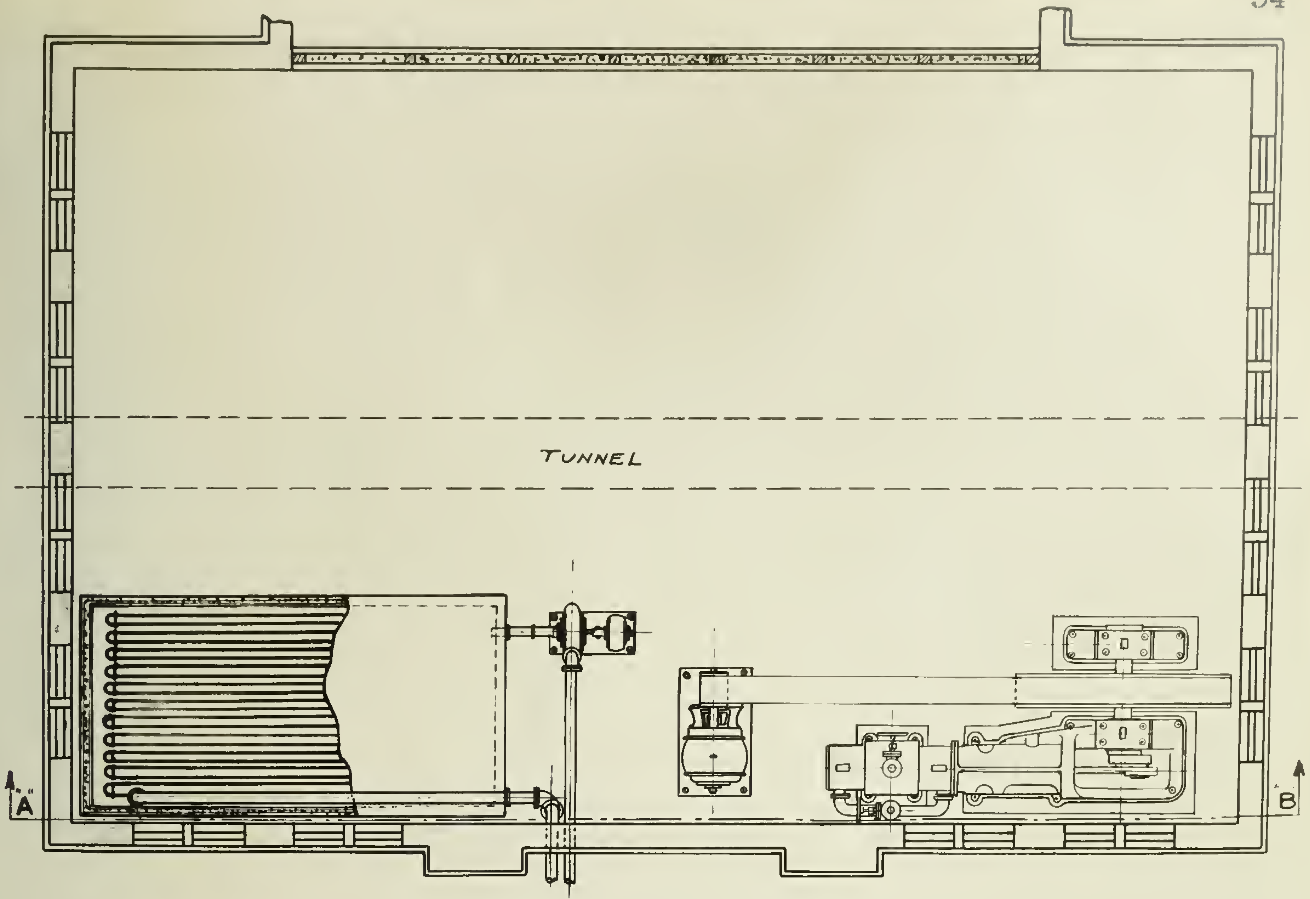


SECTION OF RINK

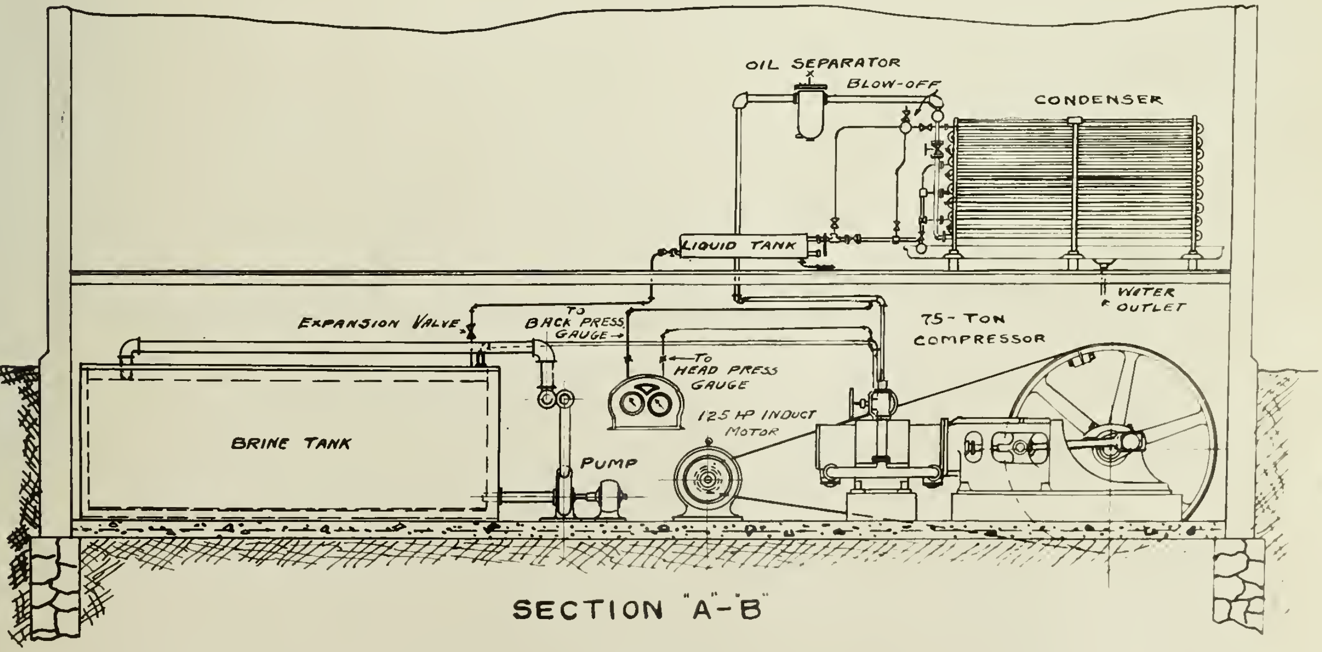
PLATE III

PIPING LAYOUT

JUNE 1, 1911 SCALE $\frac{1}{8}$"=1'-0"



PLAN ELEVATION



SECTION "A"-"B"

PLATE IV
REFRIGERATION PLANT
FOR AN
ARTIFICIAL ICE SKATING RINK
JUNE 1, 1911 SCALE $\frac{1}{16}$ = 1'-0

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